精準農業研發現況簡介

一參加 2008 年第九屆國際精準農業會議心得

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摘要

國際上現有三項較大型國際性精準農業會議，以提供議題討論平台來促進精準農業的推廣與應用，並以配合精準農業科學(技)、產業與事業的發展。2008 年 7 月 20-23 日在美國科羅拉多州丹佛市舉行的第九屆國際精準農業會議(2008 International Conference on Precision Agriculture; 2008 ICPA)，依照來自世界各地研究人員的投遞論文內容與原訂類別，將論文主題劃分為二十大項，以彰顯精準農業的重要研究與應用成果，並展示新近的研發技術與資訊管理。如此豐富而多元的精準農業內涵與應用層面，顯示出歷經二十多年的演進，精準農業已發展成為兼具理論與實務的廣面向科技。以農耕系統而言，從播種、栽培至收獲，皆可納入精準農業作業範疇，給予全方位的精準管理。

關鍵詞：精準農業、第九屆國際精準農業會議。

Current Research and Development of Precision Agriculture
一 Viewpoints from Attending 2008 International Conference on Precision Agriculture

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ABSTRACT

There are three renown international conferences held specific for Precision Agriculture (PA) with the intention to provide the forum for presentations on the current state of PA research and applications. The 9th International Conference on Precision Agriculture (2008 ICPA) was held at the Hyatt Regency Tech Center in Denver, Colorado from July 20-23, 2008. There were more than 500 attendees from all over the world with twenty subjects arranged to highlight significant research and applications in areas of PA and showcase emerging technologies and information management. Such fruitful contexts and applications indicate the multi-facets and achievements of this developing agricultural managing system. For crops cultivation, practices from seeding, planting to harvesting can all be managed precisely in a site-specific way.

Key words: Precision agriculture, 2008 International Conference on Precision Agriculture.

前言

配合精準農業(Precision Agriculture; PA)科學(技)、產業與事業的發展，目前國際上已存在三項精準農業有關的國際性會議(研討會)，均以提供議題討論平台據以促進精準農業的推廣與應用為主要目的。歷史最久的當推國際精準農業會議(International

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Conference on Precision Agriculture; ICPA)，該項會議係由美國明尼蘇達大學精準農業中心(Precision Agriculture Center, University of Minnesota)發起，自1992年舉辦第一屆起迄今第九屆止已有16年，2008 ICPA (7月20-23日)則轉由科羅拉多州立大學(Colorado State University)主辦。其次為歐洲精準農業會議(European Conference on Precision Agriculture; ECPA)，此一會議係由歐洲各國輪流辦理，自1997年由英國舉辦第一屆起迄今第六屆止已有11年，明(2009)年第七屆將輪由荷蘭於7月6-8日假Wageningen University舉行，屆時將以聯合會議方式(Joint International Agricultural Conference; JIAC)結合歐洲精準農業會議、歐洲精準畜牧業會議(European Conference on Precision Livestock Farming; ECPLF)及歐洲農業、糧食暨環境統合資訊技術會議(European Federation for Information Technology in Agriculture, Food and Environment Conference; EFITA)共同辦理。亞洲精準農業會議(Asian Conference on Precision Agriculture; ACPA)則肇始於2005年，亦為兩年一次，第一屆會議設於發起國日本，第二屆於2007年在韓國平澤市(Pyeongtaek)舉行，第三屆會議將於2009年由中國大陸(北京)舉辦。

作者此次前往科羅拉多州丹佛市參加2008 ICPA，除了因為獲遴選以口頭論文宣讀型式發表研究報告(題名：Using FORMOSAT-2 Satellite Imagery and Field Data to Monitor Growth and Predict Yield of Rice)之外，更希望能藉此行追蹤、瞭解精準農業發展現況。本次大會依照來自世界各地研究人員的投遞論文內容與原訂類別，將論文主題劃分為二十大項，分別為(1)遙感探測與氮素管理(Remote Sensing and Nitrogen Management)、(2)生質能源與精準農業(Biofuels and Precision Agriculture)、(3)精準農業技術與設計工具之經濟效益(Economics of Precision Agriculture Technologies and Design Tools)、(4)精準園藝(Precision Horticulture)、(5)使用於作物生產之植被(生)指數(Vegetative Indices in Crop Production)、(6)模式與地理統計(Modeling and Geostatistics)、(7)雜草之空間變異(Spatial Variability in Weeds)、(8)土壤之空間變異(Spatial Variability in Soils)、(9)適用農業之導引裝置、自動操作及機械人(Guidance, Auto-Steer, and Robotics in Agriculture)、(10)工程技術(Engineering Technologies)、(11)精準氮素管理(Precision Nitrogen Management)、(12)精準自(天)然資源保護(Precision Conservation)、(13)生產履歷(Traceability)、(14)資訊與網路資料管理(Information and Web-data Management)、(15)精準管理(Precision Management)、(16)感測技術(Sensor Technology)、(17)精準農業教育訓練(Education and Training in Precision Agriculture)、(18)作物之空間變異(Spatial Variability in Crops)、(19)遙感探測技術(Remote Sensing)、(20)精準農業實務(Precision Agriculture Adoption)，其中口頭宣讀論文135篇(Tables 1A-1E)，壁報論文58篇(Tables 2A-2C)。另外，也安排了兩場大會演講(plenary lectures)，提供農民和農業從業人員學習的26堂課程(A-Z presentations)，以及廠商、機構等之展示，全體參加人數近500人。

如此豐富而多元的精準農業內涵與應用層面，顯示出歷經二十多年的演進，精準農業已發展成為兼具理論與實務的廣面向科技。以農耕系統而言，從播種、栽培至收獲，皆可納入精準農業作業範疇，給予全方位的精準管理。由來自世界各國參與會議者提出的論文題目，顯示為了達到『事』與『物』的「精準管理」目標，可以因事、因時、因地、因物的結合各種知識與技術，在『人』的精心操作管理之下完成既定的處理流程，獲得可預期的結(成)果。換言之，精準農業採

Table 1A. Papers presented in the concurrent sessions of the 9th International Conference on Precision Agriculture (July 20-23, 2008) – Part I.

Type	Session	Title of paper
Oral	Remote Sensing and Nitrogen Management	Developing nitrogen algorithms for corn production using optical sensors
		Variability in observed and sensor based estimated optimum N rates in corn
		Using corn stalk nitrate testing and remote sensing to evaluate nitrogen management practices within corn fields
		Optimization of active canopy sensor spacing for directing mid-season nitrogen application in corn
		Assessing intra- and inter-field variability of corn nitrogen fertilizer need using ground-based reflectance sensors
		Nitrogen management in lowland rice
		Farm management support through remote sensing
		Remote sensing-based biomass maps for an efficient use of fertilizers
		Objective biomass assessment using an active plant sensor (Crop Circle™) preliminary experiences on a variety of agricultural landscapes
		Estimating canopy water content using hyperspectral remote sensing data
		Profitability and uptake of nitrogen application system based on remter sensing on commercial farms in the UK
		Development of an airborne remote sensing system for aerial applications
		Controller performance criteria for sensor based variable rate application
		Procedures for using active sensors to direct in-season N application on corn
		Correlation of normalized difference vegetation indices (NDVI) and crop variables with corn grain yield
		Prediction of nitrogen needs with nitrogen rich strips and ramped nitrogen strips
		Spatial patterns of nitrogen response within corn production fields
		Evaluating GreenSeeker-based in-season nitrogen management strategy for winter wheat in north China plain
	Biofuels and Precision Agriculture	Residue removal effects on soil properties within a spatially variable field
		Landscape processes impact on C turnover and energy efficiency
		Spatial variability of energy crop quality components
		Soil carbon and nitrogen mapping: how it relates to new markets and public policy
		Nitrogen management strategies for corn ethanol
		Spatial variability of corn grain and ethanol responses of nitrogen fertilizer
	Guidance, Auto-steer, and Robotics in Agriculture	Seeding and planting plots for crop performance evaluation using GPS-RTK auto steering
		Future farm: the European farm of tomorrow
		A specification for an autonomous crop production mechanization system
		Forensic methods for aligned farming systems
		Field robot simulator

Table 1B. Papers presented in the concurrent sessions of the 9th International Conference on Precision Agriculture (July 20-23, 2008) – Part II.

Type	Session	Title of paper
Oral	Economics of Precision Agriculture Technologies and Design Tools	On-farm experimentation for identification of site-specific fertilization potentials
		Economics of GPS-enabled navigation technology
		The economics of adopting PA technologies on Australian farms
		Variable rate decision support tools
		Capital investment in precision agriculture-a real options analysis
		Cost savings for multiple inputs with swatch control and auto-guidance
	Precision Horticulture	Citrus greening disease (*Huanglongbing*) detecting using aerial hyperspectral imaging
		Detection of citrus canker in orange plantation using fluorescence spectroscopy
		A software for managing remotely sensed imagery of orchards plantations for precision agriculture
		Hybrid artificial intelligence approach for grape leaf disease diagnosis system from color imagery
		Relationships between site-specific soil hydrological properties and wine production in transformed vineyard of Catalonia (NE Spain)
		Using multispectral imagery and directed sampling to estimate wine grape yield
	Vegetative Indices in Crop Production	Estimation of sweet corn yield by using individual wavelengths and water indices
		Comparison of PVI and NDVI for estimating crop ground cover for precision agricultural applications
		Identifying the factors affecting cover crop performance in row crops
		Use of NDVI measured with active optical sensors on sugarcane
		Seasonal patterns of vegetative indices over cropping systems
		Prediction of spring barley yield and grain quality using spectral reflectance and chlorophyll fluorescence
	Spatial variability in Crops	Plant and N impacts on corn (*Zea mays*) growth: what's controlling yield
		Principal component analysis of rice production environment in rice terrace region
		Using yield history to establish a baseline for on-farm research
		Site-specific identification and control of root-knot nematode in cotton in Arkansas
		Wheat quality as influenced agronomic and climatic interactions
		Precision nutrient management in sugarcane

Table 1C. Papers presented in the concurrent sessions of the 9th International Conference on Precision Agriculture (July 20-23, 2008) – Part III.

Type	Session	Title of paper
Oral	Modeling and Geostatistics	Enhancement of on-the-go soil sensor data using guiding sampling
		Mapping daily soil water status for precision irrigation scheduling
		Identifying hot spots in L'Anguille watershed using modeling approach
		Investigations on the spatial variation of soil nutrients at different scales using geostatistics and data mining techniques
		Identification of yield-limiting factors: peanut on the Texas high plains
		A spatial and spectral modeling of agronomic images
		Evaluating spatial effects induced by alternative on-farm trial experimental designs with cross-regressive variables using Monte Carlo methods
		Use of a cropping system model for soil-specific optimization of limited water
		Simulating spatial and temporal variability of wheat yield and grain protein in southern Italy
		Adapt-N: adaptive nitrogen management for maize using high-resolution climate data and model simulations
		Using Ceres Wheat for predicting site specific root growth of winter wheat under contrasting soil moisture conditions in east Germany
	Engineering Technologies	Design of harvest area measurement system for yield map correction
		Farm networks in pig housing systems
		A modbus RTU, multidrop bus design for precision irrigation
		Evaluating new spinner-disc control technology for variable-rate application of poultry litter
		A tree planting site-specific fumigant applicator for orchard crops
		Technological improvement on sugar cane yield monitor
		Development of model-based strategy for overloading agricultural crops
		Implications of standardized GNSS accuracy testing
		Precision farming sensors for sugar cane
	Precision Conservation	Using terrain attributes to identify areas suitable for grassed waterways
		Identifying critical landscape areas for precision conservation in the Minnesota rive basin
		New advance and practices for precision conservation
	Information and Web-data Management	User requirements on ICT for precision crop production
		Google maps as an aid for land-use planning decisions
	Remote Sensing	Large scale crop conditions monitoring, from countries to township scale
		Using FORMOST-2 satellite imagery and field data to monitor growth and predict yield of rice
		FARMSTAR: and operational remote sensing service for precision agriculture

Table 1D. Papers presented in the concurrent sessions of the 9th International Conference on Precision Agriculture (July 20-23, 2008) – Part IV.

Type	Session	Title of paper
Oral	Spatial Variability in Soils	Regional usefulness of nitrogen management zone delineation tools
		Zone mapping application for precision-farming: a decision support tool for variable rate application
		Delineating management zones using crop and soil variables with a multivariate geostatistics approach
		Using a fuzzy approach and web services to delineate site specific yield zones
		Precision manure management strategies across site-specific management zones for enhancing corn (*Zea mays*) grain yield
		Using soil and terrain attributes to delineate management zones in corn yield responses to nitrogen fertilization
		Terrain modeling to improve soil survey in north Dakota
		The benefits to grid sampling depend upon mathematical structure of fertilizer phosphorus and potassium design
		Assessment of automated soil mapping systems for macronutrients and soil pH using an adapted soil sampling design
		Soil electrical conductivity as a management tool in precision forestry
		The potential for variable rate subsoiling on UK farms
		Summary of forty years of grid sampling research
		Grid soil sampling adoption and abandonment in cotton production
		Variable rate application of fertilizers in western Canada
		Modeling the spatial distribution of soil pH in the state of Jalisco, Mexico
		Soil moisture, organic matter and potassium influences on EC_A measurement
		The effect of variable rate fertilizer during 8 years of precision farming management in arable farm
	Spatial Variability in Weeds	A weed growth-rate model for an autonomous plant-specific weed control robot
		Generating probability of invasive weed occurrence maps for aid in precision conservation
		Impact of precision applications of ammonium nonanoate on weed control efficacy
		3D object recognition, localization, and treatment of *Rumex Obtusifolius* in its natural environment
		Development of real-time color analysis for the on-line automated weeding operations
	Precision Agriculture Adoption	A new phase of precision agriculture in Japan
		Using high resolution remote sensing data for precision farming in Turkey
		The review of studying and using advanced technologies for site specific management in Konya, Turkey
	Precision Nitrogen Management	Effect of amending urea fertilizer with sulfur and sulfur-oxidizing bacteria strains on precision management of ammonia volatilization loss from calcareous sandy soils
		Nitrogen and water stress effects on hard red spring wheat crop reflectance, quality, and yield
		Sensor based variable rate nitrogen application in cotton

Table 1E. Papers presented in the concurrent sessions of the 9th International Conference on Precision Agriculture (July 20-23, 2008) – Part V.

Type	Session	Title of paper
Oral	Traceability	Tracing grains to field positions: overcoming the obstacles
		GPS tracking for monitoring animal, plant and soil interactions in livestock systems
		Development of an automatic agrochemical recording system for crop sprayers
		Measuring farmers' preferences for systems that improve agrochemical traceability
		Recording chemical formulations loaded intro crop sprayers-the implications for traceability and improved sprayer control
		On-board module builders, on-farm research, and precision agriculture: information technology from cotton fields to cotton gins to cotton warehouses and back again
		Application of radio frequency identification for agricultural traceability systems
		Logistics-one part of a holistic approach for farm management
	Precision Management	Precision nitrogen management based on nitrogen removal in rainfed wheat
		Mobil mapping of spatial soil properties and turfgrass stress: applications and protocols
		Optimization method for variable rate application in extensive crops in Chile
		Mapping fertilizer placement for ground spreading equipment
		Using precise GPS/GIS based barley yield maps to predict site-specific phosphorus requirements
	Sensor Technology	High capacity system for precision agriculture reconnaissance and intelligence
		Individual sensor performance and interpretational algorithms in a sensor array
		Development of a motorized digital cone penetrometer
		Multiple sensing for site-specific nitrogen top dressing: biomass, chlorophyll, and water
		Continuous analysis of grain by near infrared transmission and combines
		On-combine near infrared spectroscopy applied to prediction of grain test weight
	Education and Training in Precision Agriculture	Yield monitoring systems-improving their use and utilization through hands-on training
		Interdisciplinary team teaching of precision agriculture
		A case study approach for teaching and applying precision agriculture
		Stimulating interest in and adoption of precision agriculture methods on small farm operations
		Map@Syst-geospatial solutions for rural and community sustainability
		Teaching critical thinking skills using geospatial technology as instructional tools
		Precision agriculture technologies teaching experiences at the University of Missouri-face-to-face and online

Table 2A. Papers presented in the poster sessions of the 9th International Conference on Precision Agriculture (July 20-23, 2008) – Part I.

Type	Session	Title of paper
Poster	Engineering Technologies	Soil conductivity electrical measurement system suited to an agricultural implement (subsoiler)
		Mapping traffic patterns for soil compaction studies using GIS
		A new approach for systematic seeding and cultivating
	Modeling and Geostatistics	Modeling fertilizer deposition from a topdressing aircraft
		Reconstructing yield maps from incomplete yield monitor data
		A new approach for quantitative land suitability evaluation using geostatistics, remote sensing (RC) and geographic information system (GIS)
		An artificial neural network to understand soil compaction effects on cotton yield
	Precision Horticulture	Interpolation of wine grape quality indicators (Anthocyanin and Brix) and development of differential harvest attachment
		Temporal analysis of vase life cut roses through chemical management in Uttrakahnd (India)
		Delineating management zones for precision harvesting in vineyard of north-eastern Italy
		Identification of constraints to banana production in three eco-regions of Rwanda
	Precision Management/Precision Conservation	Site specific irrigation of peanuts on a coastal plain field
		Precision management of cattle feedlot waste
		Salt stress effects on germination, plant growth, and the accumulation of metabolites in five leguminous plants
		The influence of component crop densities and planting patterns on crop growth and soil nutrient content in a dryland maize/cowpea intercrop under contrasting conditions
		Variable rate irrigation management for peanut in the eastern coast plain
		Using the Illinois soil nitrogen test to determine optimum application rates of N in corn
		Precision management for dairy farming and automation
		A GIS database schema for small-scale precision viticulture using geosensors
	Sensor Technology	Managing soil moisture on turf grass using a portable wafe reflectometer
		Proposal for soil measuring methods using polarization optics system and texture analysis for real-time sensing
		Integration of wireless sensors network into precision farming systems
	Profitability, Adoption, and Performance Evaluation	An appraisal of the impact of agro-services corporation on food crop production: a case of cocoa farming households of Ogun State, Nigeria
		Factors influencing adoption of research results and agricultural technologies among cocoa farming households in Oyo State, Nigeria
		Precision agriculture in Arizona
		Export competitiveness of Indian horti-business industry: a model for capacity building under precision farming
	Traceability	Technology in agriculture: a case with dragon fruit

Table 2B. Papers presented in the poster sessions of the 9th International Conference on Precision Agriculture (July 20-23, 2008) – Part II.

Type	Session	Title of paper
Poster	Precision Management/ Precision Conservation	Nitrogen mineralization rate of animal manure across productivity level management zones
		Effects of slash and burn system on soil water content at Baumata forest in east Nusa Tenggara, Indonesia
		Allelopathic effects of sunflower (*Helianthus annuus*) on germination and growth of wild barley (*Hordeum spontaneium*)
		Effect of soil solarization, a non-chemical method, on the control of Egyptian broomrape (*Orobanche aehyptiaca*) and yield improvement in greenhouse grown cucumber
		Agricultural use of sewage sludge and its influence on soil electrical conductivity
	Profitability, Adoption, and Performance Evaluation	An appraisal of the impact of agro-services corporation on food crop production: a case of cocoa farming households of Ogun State, Nigeria
		Factors influencing adoption of research results and agricultural technologies among cocoa farming households in Oyo State, Nigeria
		Precision agriculture in Arizona
		Export competitiveness of Indian horti-business industry: a model for capacity building under precision farming
	Spatial Weeds Management	Precision placement of corn gluten meal for weed control in organic vegetable production
		Weed and disease distribution maps extracted from aerial images using hough transformation and gabor filtering
		Chlorophyll fluorescence imaging, PAR transmission, and canopy reflectance sensor techniques for assessment of competitive ability of wheat genotypes against weeds
		Multi-spectral imaging system for reflectance measurement application on weed detection
		Use of goats for vegetative control on military landfills
		Weed infestation maps in different systems of sugar cane
		Comparative researches concerning the assessment of methods efficiency for weeds mapping in setting up strategies for weed control at winter wheat
		Evaluation of utilization potential for methods of georeferences in the management of weed contamination of potato cultures
	Remote Sensing	Thermal characterization and spatial analysis of water stress in cotton (*Gossypium hirsutum* L.) and phytochemical composition related to water stress in soybean (*Glycine max*)
		Utilizing remote sensing images to track virus spread in wheat
		Crop water stress mapping for site specific irrigation by thermal imagery and artificial reflectance surfaces
		Evaluation SPOT 5 multispectral imagery for crop yield estimation
		Development of an unmanned aerial vehicle-based remote sensing system for site-specific management in precision agriculture
		Stay on target with SPAD in the sky
		Delineating of homogeneous soil zones using soil electrical conductivity, multi-polarization SAR and hyperpectral data
		Remote sensing of stressed areas in corn fields to prevent aflatoxins

Table 2C. Papers presented in the poster sessions of the 9th International Conference on Precision Agriculture (July 20-23, 2008) – Part III.

Type	Session	Title of paper
Poster	Remote Sensing and Nitrogen Management	Using active sensor and ultrasound sensor readings to assess plant N status
		Variable nitrogen application with satellite view
		Reflectance measurements as a tool to guide a nitrogen topdressing in sugar beet (*Beta vulgaris* L.)
		Spatial resolution for N management with active sensors in corn
		Reference strip evaluation for in-season plant nitrogen assessment in irrigated corn
		Strategy for nitrogen management using the real-time soil sensor
	Spatial and Temporal Variability in Soil, Crop, and Natural Resources	Evaluation of the effects of Telone II on nitrogen management and yield in Louisiana delta cotton
		Application of geographic information systems in socioeconomic analysis: a case of integrated soil fertility management in the Savannas of Nigeria
		Multi-thematic maps to support the decision making at agricultural production systems
		Similarity between crop management zones determined with different procedures
		Study about the space variability of different soil properties and its effect on yield, vigour, and quality in the “Doca Roija” vineyard
		Relating crop yield patterns to terrain attributes under water-limited and waterlogged conditions
		Soil management impacts on field-scale sorghum variability and productivity under three no-till crop-pasture rotation systems
		Multi-sensor estimation of claypan soil profile properties
		Making field maps for efficient soil management
		Application of yield monitor, EC mapping, remote sensing, and topographic properties in precision agriculture
		Spatial and temporal distribution of iris yellow spot virus and thrips of onion in Colorado
		Estimating layered-earth conductivity and thickness with multiple-array electromagnetic instruments
		Mapping surface soil properties using terrain and remotely sensed data in Arsanjan plain, Southern Iran
		Productivity and profitability in reclaimed sodic soils in northwest India
		The effect of zinc and boron interaction on the copper concentration in the corn leaf
		Effect of precise application of FYM, NPK, and plant density on yield of *Zea mays* in semi arid rainfed condition of India
	Traceability	Technology in agriculture: a case with dragon fruit

取一種融合『謀定而後動』及『知易行易』的哲學，透過「知識」、經由「技術」，以人為方式來調和環境造成的差異，甚至於達成預先設定的結果。此一特性，使精準農業能夠在「穩定生產」與「保護環境」上創造出雙贏局面，突破永續農業經營與發展的若干瓶頸，讓農業的永續成為可行。

傳統的合理化施肥與精準農業的定點定量施肥

「合理化施肥」一直是國內土壤界及農業化學界對農耕操作的忠告，同時亦是世界各國有識之士長期努力的方向，期以維持土壤地力並避免土質劣化。然而糧食生產需求戰勝一切逆耳忠言，自工業革命以來的兩百多年，化學產品(如肥料、農藥等)不斷地被投入農業栽培當中，以配合人口增長所需求的大量糧食生產。時至今日，環保意識抬頭、糧食安全性受到重視，人們也終於明白農業永續的重要與必要，體認沒有了農業何來糧食生產?「合理化施肥」原則因此再度受到重視，乃至成為農政部門 98 年度的重點政策與研究主題之一。精準農業談的做的是「定點定量施肥」，係依照農田各網格點(區塊)的農作物營養元素需求或吾人設定的標準，給予各點特定(site-specific)的肥料種類及施用量。這是一種「差異性處理(differential treatment)」原則的實踐，完全根據各網格點的實際狀況給予特定肥料需求量，以求取每一株(叢)農作物生長的立足點平等，而非傳統上平均肥料施用的齊頭式平等，沒有考量現實情況。如此一來，當然肥料的施用量恰如其份，肥料種類亦本乎所求，使得施肥情境可以由「合理化施肥」進一步邁入「定點定量施肥」的更高境界。農政部門既然肯定「合理化施肥」的正確性，是否更應該嘗試直接跨入「定點定量施肥」的階段以畢其功於一役，答案何在其實已一目了然。

在第九屆國際精準農業會議中，肥料的精準管理仍然沿襲過去屬於熱門研究題材，包括遙感探測與氮素管理、土壤之空間變異、作物之空間變異、精準氮素管理、精準管理、感測技術等六大項主題均有相關論文發表，尤以針對氮素(肥)的管理最多。可見肥料的精準管理普遍受到各國的重視，為了環境保護、生態維護與農業永續，如何有效而精準的定點定量施肥是成功的關鍵，從土壤與作物營養狀態的偵(檢)測直至肥料的精準施用各個環節俱是要點。目前在歐美及日本，正積極研發自走式小型全能機械人，也突破了許多技術瓶頸，能分別在水、旱田中以極短時間落差幾近同步的進行營養狀態偵測與施肥動作。未來當產品問世之後，以「定點定量施肥」從事農耕操作已非夢想，而將是例行作業中的一環。可以依照個別需求選擇適用的機械人產品，或調整設定以滿足個別狀態，讓投入的資源(材)得到充分的機能發揮。

精準農業與節能減碳

由前述精準農業在肥料施用上採行的「定點定量施肥」作法，即可瞭解操作精準農業體系對『節能減碳』的正面功效。國內的天然資源有限，農業資材的生產成本相對於國外進口同級產品普遍較高，因此確有必要實施節能減碳的相關措施來降低生產成本，並一舉多得的助益於環境的保護與農業的永續。除了肥料，「農業水資源合理化利用」是另一項臺灣地區關乎農、工、商業與民生經濟發展的重要議題，亦可藉由精準農業協助解決。雖然年降水量高達約 2,500 毫米(mm)，然而河川坡陡水急、地質脆弱不易保存的特性，以及乾、濕季節的降水分佈，常使得水源供應調配困難而出現短絀情形。加上氣候快速變遷情境帶來的混沌降水現象，乾旱頻率的增加，造成水源的不易掌握。因此，水資源的高效利用及高能產出經常是各界爭議焦點，農業用水則因為農業產值比例的偏低，2007 年僅及國內生產毛額(GDP; gross domestic product) 的 1.46%

(Agricultural Statistics Yearbook 2007)，而成為被犧牲的對象。當水資源供應有短缺之虞時，農地多被要求休耕或停灌，再以補貼形式彌補農民損失。

精準農業體系可以結合特定的知識與技術，針對農作物的灌溉需求組合必要的軟硬體，從植體水分狀態的偵測、追蹤，到定點(特定區塊或特定植株)的灌溉(噴灌、滴灌、澆灌、或溝灌等)一氣呵成。如此依照農作物植體的水分狀態施予適當的灌溉水量方式，可以節約灌溉用量，更能夠避免非必要的水源浪費，農作物則仍可維持正常生長。由施肥與灌溉的說明，讀者即可瞭解精準農業是一項活的農業操作管理體系，而非固定或一層不變的樣板、制度。它的內涵和中心思想在於因應農作物與農地所處環境的時空變化與變異，管理的重點在於鑑別、調和農田各網格地區(點)的差異，給予農作物或農地相匹配的投入與管理內涵(Yang and Lin 2002, Yang 2008)。

再者，由於採用定點定量原則，藉由預定的標準作業流程(SOP; standard operating procedure)及預設的目標，操作精準農業體系將可達到調節農作物或收穫物質量目的。固然精準農業以穩定質量及環境保護為主要，但是在不等的產量、品質及環保要求之下，將可規劃不同的標準作業流程，以獲得各種層次的預設目標。舉例言之，達到每公頃 6 噸及 3 噸產量的標準作業流程必然不同，對環境保護的程度當然有所差別。又如將收穫物之蛋白質與油分比例設定為 4:1 或 5:1，所需要的資源投入與經營管理絕對不會相同，對環境的影響程度也就不會相等。各方可依照欲達成的節能減碳水準及預設目標，研擬特定的精準農業體系，以滿足特定的條件與需求。

結語

從精準農業相關國際性會議的內容，彰顯出此一兼容學術與應用的科技領域的蓬勃發展現況，以及普遍受到世界各國重視的程度。無論係研究、教育及訓練，精準農業仍有相當拓展空間和潛力，而惟有經過落實於產業的實際運作，才能夠修飾出適合特定環境與條件的特定操作體系。知識與資訊平台是精準農業的身體，感(遙)測與影像技術是精準農業的眼睛，機械與操作流程是精準農業的四肢，決策與定位系統則是精準農業靈活的大腦，然而這一切都掌握在人的手中。當各種途徑都歸諸於同一源頭，此一源頭又能夠孕育出豐富的生命時，我們還在等待什麼?!

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